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# COMPARISON OF METHODS OF PROCESSING THE GOLD - CONTAINING REFRACTORY CONCENTRATES

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***ABSTRACT***

***Persistent ores, which are characterized by insufficient gold recovery under traditional conditions of cyanide leaching, occupy a prominent place in resource base of the modern gold mining industry. Gold in such ores is in a state of fine dispersion in sulfide minerals, most often in pyrite and arsenopyrite. Refining refractory gold ores to enhance extraction at cyanidation involves pretreatment. Traditional technologies for extraction of gold from sulfide refractory ores include flotation concentration, roasting and subsequent calcification of the calcine. However, the use of roasting is characterized by inevitable environmental pollution through gaseous emissions of arsenic and sulfur, the need for disposal of highly toxic arsenic trioxide and insufficiently high through-flow gold extraction in the technology. To date, the most environmentally friendly, highly profitable and fairly widely used ways in production practice technologies for processing refractory gold-bearing raw materials are: bacterial and autoclave oxidation. Experimental studies of the process of direct cyanidation of gold-containing flotation concentrate, as well as products of its preliminary oxidation using various methods (calcination of oxidative roasting, autoclave kecks (POX) and bacterial leaching (BIOX)) gave the following results: Cyanidation of the initial flotation concentrate provides for the extraction of Au 46.6%; the use of oxidative roasting leads to an increase in extraction of gold from 46.6% to 85%; the use of BIOX technology allows to increase the extraction of gold to 91.74%; preliminary autoclave oxidative leaching of flotation concentrate provides a stably high recovery of Au with subsequent cyanidation - at the level of 94.9 - 96.5%.***

***The introduction of autoclave and biological oxidation is an important element in the intensification of technological processes, improving the industrial safety of gold processing enterprises and improving working conditions of production personnel.***

***KEYWORDS: Gold, Refractory Gold-Bearing Concentrate, Autoclave Oxidation, Bacterial Oxidation, Roasting, Arsenic & Sorption Cyanidation***

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Original Article

## 1. INTRODUCTION

Currently, the share of metal extracted from technologically simple ores is steadily decreasing, which determined involvement in the processing of refractory ores [1-7]. According to expert estimates, up to 80% of all gold resources in Russia are concentrated in refractory ores containing finely disseminated gold and silver in sulfides, mainly in pyrites and arsenopyrite.

The resistant category includes ores, processing of which by direct cyanidation does not provide the required gold recovery. The most common cause of persistence is the fine impregnation of gold into ore-forming sulfide minerals, mainly in pyrite ($FeS_2$) and arsenopyrite (FeAsS), which have a dense structure, which in turn makes gold inaccessible to cyanide solutions at cyanidation redistribution [8]. As a result, cyanidation is either not possible at all or is characterized by low recovery rates. Therefore, to achieve high recovery of gold from refractory ores and concentrates at the cyanidation stage, their preliminary preparation is necessary, which consists in the destruction of the sulfide matrix, namely, in the oxidation of sulfides. The most common methods of oxidation are: oxidative roasting, bacterial oxidation and autoclave oxidation [9-16].

The most important problem in processing of refractory gold-bearing pyrite-arsenopyrite materials is the removal, neutralization and disposal of highly toxic arsenic. The MPC of arsenic in the air of working area is 0.01 mg / $m^3$, and the MPC of arsenic in wastewater is 0.05 mg / $dm^3$.

Oxidizing roasting followed by cyanidation of calcine is one of the most common methods for processing sulfide gold-containing concentrates. During oxidative roasting, gold-containing sulfides oxidize and turn into a porous mass of oxides that is well permeable to cyanide solutions. The firing method is quite simple, well mastered and is still used in Canada, South Africa, Australia and other countries. However, the use of roasting is characterized by inevitable environmental pollution by gaseous emissions of arsenic and sulfur, the need for burial of highly toxic arsenic trioxide, and the formation of low-melting compounds films during the burning process and the removal of gold into arsenic sublimates reduce gold extraction in technology [8-11].

To date, the most promising from an economic and environmental point of view, and quite widely used in production practice technologies for processing refractory gold-bearing raw materials are: bacterial (BIOX) and autoclave (POX) oxidation [12-16]. The advantages of these technologies are the absence of any toxic gaseous emissions, the removal of arsenic from technologies in the form of low-toxic arsenate of iron and compared to roasting, a higher extraction of gold at the stage of cyanidation [17-18].

## 2. RESEARCH METHODS

In this paper, we consider four options for processing refractory flotation concentrate (table 1): direct cyanidation, cyanidation of the cinder of oxidative roasting, autoclave kecks and bacterial leaching.

**Table 1: The Chemical Composition of Samples Flotation Concentrate**

| Component | Content% | Component | Content, % |
|---|---|---|---|
| Cu | 0,081 | $K_2O$ | 1,38 |
| Pb | 0,015 | $S_{obs}$ | 21,5 |
| Zn | 0,052 | $S_s$ | 19,8 |
| Sb | 0,070 | $Fe_{general}$ | 19,7 |
| Hg | 0,00048 | $C_{general}$ | 0,91 |
| $SiO_2$ | 27,6 | $C_{org}$ | 0,12 |
| $Al_2O_3$ | 8,18 | As | 7,20 |
| CaO | 2,28 | Au, g / T | 55,4 |
| MgO | 1,16 | Ag, g / T | 11,6 |
| $Na_2O$ | 1,14 | | |

The mineral composition of the concentrate consists of 50.2% of pyrite sulfide minerals (35.5%) and arsenopyrite (14.7%). A microanalyzer of pyrites showed the presence of arsenic species with an as content in them from 0.7 to 5.1%.

## 3. RESEARCH RESULTS

It has been established that direct cyanidation of a concentrate with a particle size of 66% of the class of -0.071 mm makes it possible to achieve extraction of Au into a solution in the range of 38.81 - 46.57%. Pre-grinding the flotation concentrate to 100% of the -0.020 mm class leads to an increase in gold recovery during cyanidation to 56% (table 2).

**Table 2: Investigation of the Effect of Composition of Flotation Concentrate on the Extraction of Gold during Cyanidation**

| Cipher Experience | Au Content in Solution, mg / l | Consumption, kg / t | | Output Kek, % | Au Content in Solid, g / t | | Extract Au, % |
|---|---|---|---|---|---|---|---|
| | | NaCN | CaO | | Before Cyanation | After Cyanidation | |
| **Cyanization of the Flotation Concentrate of the Initial Size** | | | | | | | |
| FB-3 | 6,6 | 5,4 | 0,9 | 100 | 55,4 | 29,6 | 46,57 |
| FB-4 | 6,3 | 5,4 | 0,75 | 100 | 55,4 | 33,9 | 38,81 |
| **Cyanide Crushed Flotation Concentrate** | | | | | | | |
| FB-6 | 7,23 | 7,8 | 1,3 | 97,6 | 55,4 | 24,9 | 56,15 |
| FB-7 | 7,53 | 7,6 | 1,1 | 99,47 | 55,4 | 24,5 | 56,01 |
| FB-9 | 8,2 | 6,5 | 0,7 | 98,4 | 55,4 | 24,6 | 56,32 |

The use of oxidative roasting can increase the extraction of gold from the flotation concentrate from 46.6% to 85%. The preliminary mechanical activation of the calcine gives an increase in the extraction of gold (regarding the cyanidation of the calcine without mechanical activation): by 6.5% -when grinding within 3 minutes, by 10%- when grinding within 20 minutes. Mechanical activation of the calcine for 20 minutes leads to ultrafine grinding of the product, as a result of which the surface of interaction of the particles with the leaching agent increases sharply and the specific cyanide consumption increases 3.6 times: from 10.6 kg / t to 38 kg / t (Table 3). The degree of deracemization during firing was 92%.

**Table 3: Investigation the Effect of Preliminary Roasting of a Flotation Concentrate and Mechanical Activation of the Calcine, Obtained on Extraction of Gold into the Solution during Subsequent Cyanidation**

| Cipher Experience | Au Content in Leach Solution, mg / l | Consumption, kg / t | | Keck exit, % | Au Content, g / t | | Extract Au, % |
|---|---|---|---|---|---|---|---|
| | | NaCN | CaO | | Before Cyanation | After Cyanidation | |
| **Cyanization of Cinder without Preliminary Mechanical Activation** | | | | | | | |
| BES-compress-1 | 14,8 | 10 | 12 | 99,7 | 67,13 | 11,27 | 83,27 |
| BES-compress-2 | 16,3 | 11,1 | 13,2 | 99 | 67,13 | 9,14 | 86,52 |
| **Cyanization of the Cinder with Pre-Mechanical Activation for 3 Minutes** | | | | | | | |
| FB-11 | 13,1 | 15 | 17,6 | 89,1 | 67,13 | 6,43 | 91,46 |
| **Cyanization of Cinder with Preliminary Mechanical Activation for 20 Minutes** | | | | | | | |
| Fb (o) -1 | 14,1 | 39,9 | 11,9 | 91,5 | 67,13 | 2,93 | 96,01 |
| Fb (o) -2 | 14,3 | 36,1 | 11,7 | 92 | 67,13 | 3,82 | 94,76 |

Studies of the effect of autoclave oxidation of a flotation concentrate on the extraction of gold into solution during subsequent cyanidation showed that during cyanidation of AOW kecks obtained by varying the opening temperature of the flotation concentrate in the range of 200-225 C, there is a consistently high gold recovery: at 94.91 - 96, 47%. At the same time, the specific consumption of cyanide and lime is at the level, kg/t: 17.8 - 25.1; 6.2 - 7.1, respectively. The minimum consumption of sodium cyanide corresponds to the leaching of gold from the AOW keck obtained at a temperature of 200 ° C; however, under these conditions, the process lasts 90 minutes, and at a temperature of 225 ° C - 30 minutes.

**Table 4: Main results of Cyanidation of AOB Kecks**

| Cipher Experience | Consumption, kg / t | | Output Keck, % | Au Content, g / t | | Extract Au, % |
|---|---|---|---|---|---|---|
| | NaCN | CaO | | Before Cyanation | After Cyanidation | |
| BES-1 | 25,1 | 6,9 | 95,9 | 86,39 | 4,29 | 95,24 |
| BES-2 | 23,3 | 7,0 | 96,8 | 88,44 | 4,26 | 95,34 |
| BES-3 | 17,8 | 7,1 | 99,0 | 83,52 | 4,51 | 94,65 |
| BES-4 | 21,4 | 6,5 | 97,4 | 83,76 | 4,38 | 94,91 |
| BES-5 | 19,4 | 6,2 | 97,2 | 80,32 | 2,92 | 96,47 |
| BES-6 | 19,6 | 6,2 | 97,1 | 80,85 | 3,59 | 95,69 |

As a result of autoclave oxidation of sulfide arsenic material, significant volumes of technological solutions are formed, containing high concentrations of arsenic, iron and sulfuric acid. To efficiently precipitate arsenic from autoclave solutions, it is necessary to conduct their high-temperature, staggered neutralization, which allows arsenic to be converted to stable iron arsenates during long-term storage.

Experiments on the bio-oxidation of sulfide concentrate were performed in collaboration with the Institute of Microbiology, Vinogradsky. With different technological parameters (modes 1 and 2), two batches of bio-kecks were developed:

- batch 1 (mode 1)– W: T = 6,7, oxidation time - 5 day., t=40 °C;
- batch 2 (mode 2) – W: T = 5, oxidation time - 5 day., t=40 °C.

The degree of oxidation of sulfide sulfur is: 68% for Bishkek-1, 50% for Biokek-2, and the degree of dearsenization - 56%, 45%, respectively. It was revealed that the preliminary bio oxidation of the flotation concentrate allows to increase the extraction of gold during subsequent cyanidation to 91.74% (Table 5).

**Table 5: Results of Cyanidation of Flotation Concentrate Bio-Oxidation Kecks**

| Cipher Experience | Consumption, kg / t | | Output Keck, % | Au Content, g / t | | Extract. Au, % |
|---|---|---|---|---|---|---|
| | NaCN | CaO | | Before Cyanation | After Cyanidation | |
| 24 Часа | | | | | | |
| BioB1-1 | 26 | 12,4 | 97,5 | 55,17 | 4,65 | 91,74 |
| BioB2-1 | 29,4 | 14,7 | 94,6 | 57,2 | 7,43 | 88,08 |

Arsenic, as the previous case, is removed from bio oxidation solutions in the form of iron arsenate that is stable during long-term storage by neutralization.

## 4. CONCLUSIONS

The use of hydrometallurgical technologies for processing refractory pyrite-arsenopyrite gold-bearing concentrates is characterized by high gold recovery at the cyanidation stage, absence of any toxic gaseous emissions and removal of arsenic from the technological cycle in the form of low-toxic iron arsenate.

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